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Objective.—The current conflict in Afghanistan is the first major military action in which the United States and other North Atlantic Treaty Organization (NATO) forces have found themselves regularly engaged in combat at high altitudes. However, high altitude warfare is not a new concept in Asia by any means. Methods.—This article will offer a short general historical review of high altitude warfare in Asia and then specifically address some of the operational challenges faced by troops carrying out missions at high altitude in the ongoing conflict in Afghanistan. Additionally, there will be discussion of evidence-based interventions being used to attempt to maintain optimal health of the warfighter at high altitude in this theater of operations. Conclusions.—Years of research into how to alleviate the problematic nature of military operations in the high altitude environment has resulted in extensive risk management recommendations from the US Army, specifically aimed at preventing altitude-related casualties.

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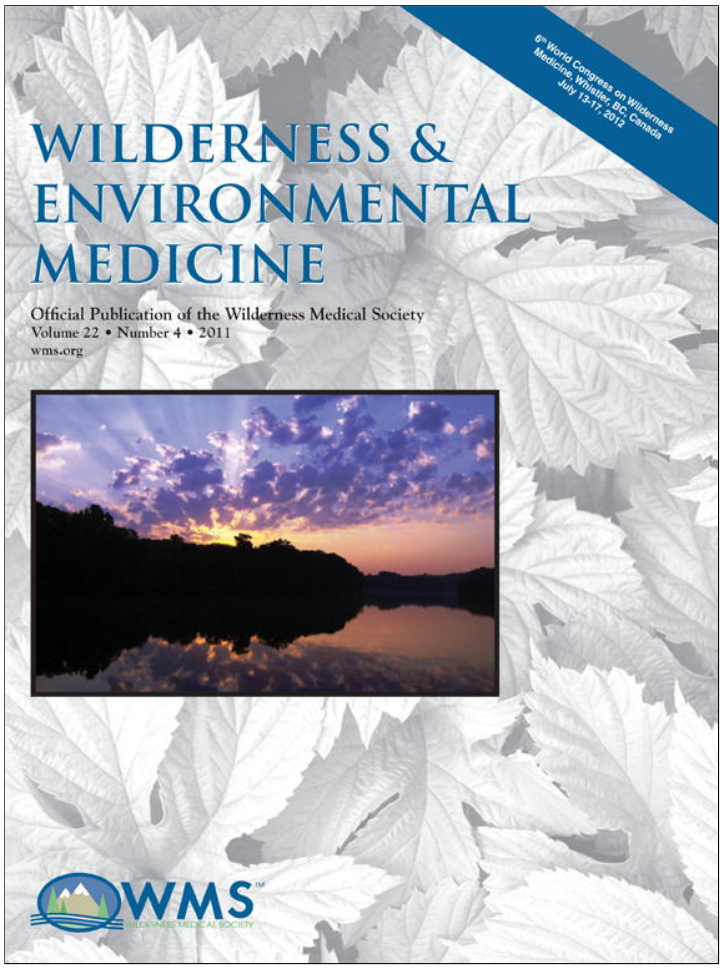

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OPERATIONAL AND TACTICAL MEDICINE

Fighting in Thin Air: Operational Wilderness Medicine in High Asia

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Key words: high altitude, altitude sickness, acclimatization, history, military

Introduction

Since shortly after the turn of the 21st century, the militaries of a number of Western countries have found themselves engaged in prolonged combat in the Eastern Hemisphere nations of Iraq and Afghanistan. A unique aspect of the ongoing conflict in Afghanistan is that it is the first major military action in which US and other North Atlantic Treaty Organization (NATO) forces have found themselves regularly engaged in combat at high altitudes. Nonetheless, as Rock wrote in the introduction to *Mountains and Military Medicine*, ". . . the mixture of soldiers and mountains is not a historical aberration. The United Nations, in designating 2002 as the 'International Year of the Mountains,' noted that 23 of the 27 armed conflicts ongoing in the world at the beginning of 2002 were being fought in mountain areas."[1]

The mountain environment is fraught with many environmental hazards—to civilian and military sojourners alike. However, frontline military personnel, unlike civilians visiting high altitude areas for recreational purposes, often have the terms of their "visit" dictated to them by a host of strategic or tactical considerations. For example, a military unit based near sea level and inserted by helicopter into a combat zone at an altitude of 3000 m or greater may, at times, find it unrealistic to rigorously adhere to recommended acclimatization schedules in order to avoid altitude illness. When deployed in an area of combat operations, the soldier must endeavor to eat, sleep, and fight regardless of physical terrain, weather, and natural or man-made hazards. It thereby stands to reason that ignoring the realities of the high altitude mountain environment during a military action is done at the risk of seriously denigrating the capacity for troops to successfully carry out any given mission. It can certainly be argued that mountain environments are a great equalizer in conflicts between the world's most modern high-tech military forces and third-world guerrillas who may have the insight, daring, acclimatization, and/or genomic adaptations to use the terrain and/or environmental elements to their tactical advantage. Mountain areas offer secure refuge and excellent ground for small-unit tactical maneuvers, whereas large organized troop movements that have less tactical flexibility may well be at greater risk from the mountain environment. Such limited flex-

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ibility in planned and scripted military operations in the high altitude setting heightens the threat of a significant reduction in troop strength because of altitude illness and hypoxia-related reductions in physical and cognitive performance—which can be further exacerbated by factors such as intense physical activity during a period of rapid ascent. This article will offer a short general historical review of high altitude warfare in Asia and then specifically address some of the operational challenges faced by troops carrying out missions at high altitude in the ongoing conflict in Afghanistan. Additionally, there will be some discussion of evidence-based interventions being used to attempt to maintain optimal health of the warfighter in the thin air of this theater of operations.

Historical Aspects of Conflict in High Asia

GENERAL

Since the time of the great Greek military leaders Xenophon and Alexander's martial adventures several hundred years B.C. into Central Asian locations such as Kurdistan and Afghanistan, large organized forces have marched and fought in high mountain areas at altitudes over 4000 m. During the 18th and 19th (and the first few years of the 20th) centuries, such Central Asian military and/or political adventures were referred to, in Rudyard Kipling's words, as the "Great Game." From the time Great Britain gained control of India some 300 years ago, first through commercial means—via the British East India Company—and then by means of official British government colonial rule (ie, the British Raj, between 1858 and 1947), there was concern about Russia's intentions in Central and South Asia. The British, at any rate, saw the so-called Great Game as high stakes territorial competition—with Britain wishing to retain the riches of India, and Russia wishing to claim them.[2]

The arena for the "Game" was a vast region punctuated by over 3000 km of mountainous terrain—with a plethora of high summits exceeding 6000 m and few passes lower than 5000 m—running northwest to southeast across Asia, forming a natural barrier between Russia, Mongolia, and China to the north and Iran, Afghanistan, Pakistan, and India to the south. Of great interest to both sides were mountain passes by which an army from the north might invade India, although with sober consideration it would have been abundantly clear that there are few places on Earth less suited to war because of terrain, extreme cold, high altitude, and scarce availability of food and water. Not surprisingly, very little military action of significance ever took place in these high and wild areas during the years of the Great Game. Perhaps the only action of lasting strategic value occurred in the closing years of the "Game"— in the form of Francis Younghusband's British mission to Lhasa, Tibet ("mission" being the term then used to mean diplomats plus small army) in the years 1903 to 1904.[3–5] Eager for a neutral buffer state from other Central Asian nations potentially hostile to British India, the British government dispatched Younghusband and his military detachment to the Tibetan capital for negotiations. The Tibetan government did not welcome the British force, and Younghusband found it necessary to fight his way to Lhasa, engaging the Tibetans (and their ancient weapons) in numerous one-sided battles, often at altitudes exceeding 4000 m. In fact, there were at least 2 documented battles between the British (involving their Gurkha and Sikh Pioneer troops) and the Tibetans at altitudes exceeding 5600 m.[3] These engagements very likely stood as a high altitude battle "record" for nearly 90 years, only to be broken during the Pakistan-India conflict when the opposing armies of these countries fought to secure the Line of Control in the Kashmir border region. While the British government and public were rather appalled at the extent of the bloodshed during the 1903 to 1904 mission, Younghusband did undoubtedly fulfill his assignment. Tibet and Great Britain found themselves on relatively good terms for the next several decades until the post-World War II takeover of Tibet by China.[3,4]

In the more recent history mentioned above, the Indian army has waged (and continues to anticipate) battles with Pakistan and China along the spine of the Himalayas. In 1962, the Chinese attacked India in several places along the Sino-India frontier at altitudes well over 4000 m. This was the first large-scale confrontation between military forces at such altitudes. Because India was taken by surprise, troops were immediately rushed to 4000 m and above with summer equipment. Morbidity from mountain sickness alone exceeded 20% in some companies.[6]

The Himalayan region of Kashmir (in the northwest corner of present-day India, adjacent to the Pakistan border) has also been disputed territory since at least the 17th century, when Britain and Russia vied for control of Central Asia during the Great Game. More recently, as an adjunct to the ongoing Kashmir conflict, India and Pakistan have (since 1985) been fighting in the mountains of the Karakoram Range. Astonishingly, the fighting has taken place in the watershed of the Siachen Glacier—a 76 km wedge separating India from her 2 traditional adversaries, Pakistan and China. Three Indian battalions defend this varied borderline. The Siachen runs through some of the world's highest and least accessible mountains. On and around this glacier, India maintains regularly manned military posts in locations as high as 6447 m. Of the 2000 dead and 12 000 injured

soldiers India has suffered since the fighting started on the Siachen in 1985, an estimated 90% are due to high altitude and cold.[7] This battle has been essentially immobile, not surprisingly, and has consisted of little to break the monotony of stalemate aside from minor raids and short artillery duels directed at glacial outposts positioned above 6000 m. However, the most fierce high altitude engagement between India and Pakistan in recent years has arguably been the 1999 Kargil Conflict in Kashmir. In the summer of 1999, Pakistani forces occupied peaks in the Indian-held Kargil region that barred Indian access to the remote reaches of the Kashmir state. The high altitude environment largely shaped a campaign that lasted 74 days and cost each side more than a thousand casualties. In a situation mirroring the aforementioned Indian-Chinese conflict in the early 1960s, most of the Indian Army forces that deployed to Kargil were thrown into battle with little time to adapt to the drastic altitude change (although the Indian military doctrine recognized the need for gradual acclimatization). Many Indian troops were sent from near sea level to 4000 to 4500 m within 2 days, suffering the predictable consequences of altitude illness.[8] Not unexpectedly, this was thought to have contributed to India's initial failures in the conflict. An important tactical lesson reinforced in Kargil by the Indian Army, however, was that the timeless "fire and maneuver" offense with well-trained light infantry and artillery is as decisive in mountain warfare in the present day as it was, for instance, in Greece and Italy during the Second World War. Air power has been consistently shown to provide less than optimal close support in the mountain environment, which further emphasizes the need for troops on the ground (in high altitude battle zones) who are well-acclimatized.[8]

AFGHANISTAN

Although the British government had a military presence in Afghanistan in the 1840s and 1870s —with variable success[9,10]—the fear of Russia harbored by the British Raj for so many years was finally realized (though many years after the British had officially left India to the Indians) when, in 1978, the former Soviet Union decided to intervene in the ongoing political struggles between Afghan rebels and their government. The Afghan landscape—high and wild snow-clad mountains and barren sandy wastes—provided shelter and sanctuary for the Afghan guerilla forces who were at home in such an environment. Regular Soviet military forces did not find the physical challenges of such country to their liking and, in addition to trying to sort out the many independent guerrilla factions, were frustrated in their efforts to bring the Afghans to heel.[9–11]

> Despite superior equipment and unopposed air assaults, the Russian armies did not tolerate the mountain hardships, and finally the Afghan rebels, poorly disciplined and led though they were, used the mountainous wasteland better than the Russian troops, and forbade them ground control . . . . Belatedly, the Russians recognized that their troops had not been adequately prepared for the terrain and the extreme climate encountered in Afghanistan, and they established a mountain warfare training center in Russia . . . . [however] After 10 years the Russians could not prevail [in Afghanistan] and, after an ignominious stalemate, withdrew.[6]

While the Soviet experience reinforced Afghanistan's reputation as a graveyard for foreign armies after the disastrous British experience in the 1840s, it should be clearly emphasized that Afghanistan actually has a long history of being frequently, if temporarily, subdued. After Alexander the Great "conquered" the country in the years B.C., Genghis Khan and his Mongols ravaged Afghanistan's 2 major cities in the 13th century. In 1504, Babur, founder of the Mughal Empire in India, assumed the throne in Kabul and reigned until his death in 1531. And, subsequent to the aforementioned experience in the 1840s, the British successfully occupied Afghanistan for several years in the late 1870s and early 1880s.

Physiological Realities and Their Impact on Operational Success

The long history of military adventures and/or misadventures in Afghanistan highlight many of the obstacles such as rugged landscape, altitude, and temperature extremes (summer temperatures of 49°C in northern valleys and winter temperatures of well less than −10°C even at the moderate altitude of 2000 m are common) that make mountain warfare so difficult. Many of the same physical and environmental—not to mention social—challenges that have made life very difficult in the past for foreign military forces continue to present substantial obstacles for NATO forces who have found themselves on Afghan soil since the autumn of 2001.

As already suggested, of the aforementioned natural obstacles presenting problematic factors for Western troops presently in this region, high altitude is arguably the most unique operational aspect of combat in Afghanistan. It has not been at all unusual for major battles to be fought at altitudes approaching 3000 m (such as Operation Mountain Storm [2500 m], Korengal Valley [2560 m], and Operation Buzzard [2700 m]), and numerous major engagements have been undertaken in locations at altitudes of over 3000 m (such as Takur Ghar [3191 m], Operation Warrior Sweep [3260 m], and Operation Snipe [3962 m], including the key encounter at Tora Bora [4382 m]).[12,13]

Perhaps not surprisingly, this has frequently led to debilitating problems with mountain sickness for troops who are often quickly inserted from their low altitude bases to a high altitude battle zone by helicopter. After Action Reports from Joint Special Operations Command, the US Marine Expeditionary Force, and the US Army 10th Mountain Division have highlighted the high altitude medical issues. Consistent themes include: "combat ineffective," "cannot pursue enemy," "aborted missions from altitude sickness," and "at 8,000-9,000 ft all our soldiers were completely exhausted within hours."[13] During Operation Anaconda, 14.6% of combat-related casualties cared for by one US Army Forward Surgical Team were cases of severe acute mountain sickness (AMS).[14] Unlike the civilian high altitude sojourner who plans to "take it easy" in the early phase of acclimatization to altitude if they adhere to current suggested medical advice, military personnel are unlikely to be able to avoid physical overexertion early in the course of altitude exposure. In addition to hard physical work, the physiological stresses of inadequate nutrition and hydration, sleep deprivation, fear, and exposure to temperature extremes may serve to heighten the likelihood of troops being rendered combat-ineffective by altitude-related pathology.

In fact, it is no exaggeration to suggest that military history is full of examples of environmental factors affecting the course of battles and even entire wars. Heat, cold, and high altitude have often had significant influence on the success or failure of many martial operations. Recognizing the importance of environmental influences on operational success, the US Army maintains the Research Institute of Environmental Medicine (USARIEM) in Natick, Massachusetts. Although USARIEM has been the main institution and facility for military environmental medicine and exercise physiology research in the United States since 1961, it traces its institutional lineage back to 1927 and the creation of the Harvard Fatigue Laboratory. This laboratory of human physiology at Harvard University was conceived by Lawrence J. Henderson and directed by David Bruce Dill until its dissolution in 1946.[15]

Scientists at USARIEM are involved with basic and applied research to determine how factors such as heat, cold, altitude, physical training, hydration, and nutritional factors (for example) may affect the health and performance of warfighters, and what can be done to prevent the degradation of performance of these military personnel. Existing resources for research at USARIEM include ". . . heat and cold chambers, immersion pools, altitude [hypobaric] chambers, animal research facilities, a biomechanics laboratory, exercise physiology labs, an in vivo bone research lab, and multiple biochemistry wet labs."[16] In addition to USARIEM's on-site hypoxic "exposure" capabilities in Natick, the off-site USARIEM high altitude human physiology laboratory on top of 4302 m Pike's Peak, Colorado, has been of particular interest to the military since the commencement of combat operations in Afghanistan in 2001. The risk of altitude illness and reduced work performance associated with rapid ascents of warfighters to well over 3000 m has induced USARIEM to work to "develop rapid acclimatization strategies with intermittent hypoxia, explore nutritional supplements (notably carbohydrate) to boost performance at altitude, and construct staging tables to provide recommendations on rates of ascent."[16] For example, since the early days of the present Afghanistan conflict, USARIEM scientists and their US Air Force Academy colleagues have been studying military personnel stationed at the US Air Force Academy, Colorado, in order to assess the advantage of having preacclimatized personnel ready for rapid deployment to high altitude areas.[17,18]

From a military operation point of view, perhaps the most significant problem at high altitude is that time and exposure to the hypoxic environment are needed in order to attain and maintain a state of acclimatization. It is generally not practical to station large numbers of troops in any kind of permanent or semipermanent fashion at high altitude in Afghanistan, in large part due to the simple fact that the major US or NATO headquarters' infrastructure tends to be positioned in-country at relatively low altitudes. This reality has prompted USARIEM scientists and other investigators working on physiological problems relevant to military operations in mountain regions to consider alternative means to address the potential adverse outcomes on health and performance from the stresses associated with high altitude—stresses such as exhaustion, cognitive deficits, sleep loss, dehydration, acute mountain sickness, and other altitude-related maladies. Nevertheless, the study of graded ascents and "staging" altitudes for purposes of warfighter acclimatization is certainly of interest to the military because of strong anecdotal and evidence-based support of its effectiveness.[17–22] Key points for altitude acclimatization procedures are consequently given as: 1) ascend high enough to induce adaptations, but not so high as to develop altitude illness; 2) unacclimatized soldiers should not ascend above 2400 m; 3) stage 4 to 6 days between 2000 to 2400 m; 4) stage 7 to 14 days between 1400 to 2000 m; 5) staging reduces AMS incidence for altitudes 1000 to 2000 m above the staging altitude; 6) graded ascents above 2400 m should not exceed 300 m/d; 7) graded ascents greater than 300 m/d (above 2400 m) should include a rest day at each higher altitude.[23] However, it is realized that these guidelines may not always be practical options for troops for any number of reasons.

Alternatives (and adjuncts) to traditional staging and graded ascent that have been investigated with the aim of reducing high altitude-related degradation of health and performance can be broadly characterized as: 1) predeployment "acclimatization" via intermittent altitude or normobaric hypoxia exposure[24–30]; and 2) enhanced nutritional support.[31–33] The nutrition findings suggest that "A carbohydrate-rich diet, as well as frequent ingestion of small amounts of carbohydrate-rich foods or liquids during prolonged, difficult tasks, will sustain performance at the highest level possible for a given altitude."[23]

The scientifically informed measures utilized to combat medically adverse outcomes in troops operating at high altitude such as novel acclimatization strategies, risk management through screening, and improved hydration and nutrition can be very useful when intelligent planning and operational realities intersect. Needless to say, frequent adaptation of the warfighter to tactical operational needs in a harsh environment points to the need for useful diagnostic and treatment methods when preventive procedures are not sufficient to keep altitude illness at bay. Current suggested monitoring and assessment in the field utilizes measurement of pulse oximetry, resting heart rate, and presence or absence of signs and symptoms of altitude illness. It is also recommended that "all members of a unit have knowledge of valid metrics for monitoring unit and individual acclimatization status."[23] Military recommendations regarding pharmaceutical use for purposes of prophylaxis and treatment of various forms of altitude illness do not vary significantly from recently published (civilian) medical guidelines,[34] with one notable exception—the military's inclusion of the warning statement that ". . . acetazolamide will worsen performance of high intensity tasks that involve either prolonged whole-body effort or rapidly repeated local muscular effort."[23]

Years of research into how to alleviate the problematic nature of military operations in the high altitude environment have resulted in extensive risk management recommendations from the US Army specifically aimed at preventing altitude casualties. These guidelines have been developed for use by field commanders and senior noncommissioned officers who are not necessarily well versed in the fine points of high altitude medical problems, but are nonetheless responsible for the well-being of their troops. The risk management document is introduced with the statement: "Altitude illness casualty prevention is a command responsibility." Recommended steps include: 1) identifying hazards (eg, rapid ascent, lack of acclimatization, dehydration, fatigue, recent respiratory infection, and lack of fitness); 2) assessing hazards (eg, use of calibrated barometer or altimeter, topographic map, and GPS); 3) developing and implementing controls (eg, soldier and leadership education, actual training at altitudes above 2400 m, maintenance of health and nutrition, buddy checks for signs of altitude illness, appropriate use of medication to prevent and treat altitude illness, and encouraging soldiers to speak up about symptoms of altitude illness); 4) supervising and evaluating controls (eg, basic education for all soldiers on the prevention, recognition, and treatment of altitude illness and monitoring for indicators of increasing altitude illness risks such as an increase in altitude-related complaints and casualties).[23] United States Army schools train and utilize these recommendations, as reflected in the Infantry Center's literature that states "Team leaders make sure soldiers are wearing the right equipment in the proper manner and they constantly monitor each of their soldiers for signs of heat or cold weather injury, as well as altitude sickness. Good supervision, coupled with an equally good battle buddy system, will reduce casualties drastically."[35]

Without doubt, justification of the financial cost of developing useful and practical methods of preventing or treating altitude-related illness in military personnel might possibly be a more straightforward process if the impact of such illness on the physical and cognitive aspects of soldier performance could be accurately quantified. That, however, is easier said than done—lack of International Classification of Diseases codes for altitude illness and the fact that altitude illness is often treated by a field medic (ie, few hospitalizations) make its influence on soldier performance hard to objectively quantify. Furthermore, even more than extremes of cold or heat, high altitude can be an adversary that may surreptitiously influence health and performance long before obvious signs and symptoms of acute mountain sickness or other altitude-related illness manifest themselves. That said, many reports that filter back from Afghanistan characterize the problem as well as the efficacy of prophylactic or therapeutic medical strategies being utilized at high altitude. A 2004 After Action Report from the 10th Mountain Division such as the following is typical:

> *Dilemma:* Many Soldiers had problems due to altitude . . . Soldiers deployed about 6,000′ to 8,500′ by CH-47. Eventually moved up to about 10,500′. Almost everyone had some problems with the altitude at first. Some were treated with O2, Diamox, and dexamethasone. *Lesson Learned:* Rapid deployment of Soldiers to above 8,000′ will almost always produce altitude illness or decreased function.

On the other hand, a report from a unit of the 101st Airborne (Air Assault) Division demonstrated the efficacy of prophylactic Diamox during a helicopter insertion to 11 000 feet, stating "At the end of this operation,

we had zero individuals complaining of or needing MEDEVAC for altitude-related illnesses."[36]

An email to USARIEM in June of 2003 from the surgeon for Joint Task Force 5 is another example:

> . . . This Special Operations task force conducted operations throughout the country in support of Operation Enduring Freedom. Many of these operations entailed significant altitude exposures. One of the most useful set of documents that I encountered in providing medical support for these operations was the series of information papers that you forwarded from USARIEM covering various aspects of altitude physiology and treatment of altitude illnesses . . . our primary base was in Bagram [1491 meters (4,894 ft)] . . . [and] the paper on rapid ascents to higher altitudes after prolonged acclimatization at 5,000 ft was particularly helpful.

Conclusions

In the textbook *The Medical Aspects of Harsh Environments*, a chapter titled "Selected Military Operations in Mountain Environments: Some Medical Aspects"—written by an individual who had been one of the world's foremost authorities on high altitude medicine prior to his death in 2009, Charles Houston, MD—concludes, "It is ironic that despite sophisticated weapons, clothing, and food; despite airpower and advanced transport; repeated failure to learn such basic lessons [about mountain warfare] from the past has continued to cause avoidable casualties and has too often led to defeat. Mountainous terrain is a special circumstance, one greatly complicating the other hazards of war."[6] One can only hope that the science and practice of wilderness medicine, so well-suited to the high, wild, and remote settings of Afghanistan, will aid the efforts of Western governments and their armed forces as they struggle to bring some sense of stability to a country that has known little regularity other than that of a steady and dreadful series of violent conflicts over the course of much of its recorded history.

Disclosures

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